Water-permeable ground covering and method for producing a ground covering

The invention relates to a water-permeable ground covering for application to a substratum, in which case the superstructure of the ground covering is a combination of compacted, mineral aggregates and organic binding materials. The invention further relates to a method for producing a ground covering.

The consolidation of surfaces by ground coverings to produce roads, public places, building covers and other surfaces on which it is possible to walk or drive is a well-known technique. Concrete, asphalt, stone and wooden coverings are common. The disadvantage with regard to draining off surface water is the low level of or even absence of water-permeability; there is therefore often talk of a sealing of the surfaces, attempts being made to deal with this by means of drainage systems, which in most cases are expensive.

An ecologically undesirable phenomenon accompanying surface-sealing is the increased loading on river courses that change into raging torrents when there is heavy or persistent downpours of rain or as a result of melt water. The consequences are catastrophic: ever more frequently floods occur, communal sewage plants are overloaded and fail, groundwater levels drop.

Further demands are made with regard to constructional properties. These relate to performance in the event of moisture, resistance to pests, acoustic properties, reaction to chemical influences and to fire. The durability of a ground plays a big rôle as the most important demand, with properties such as pressure-resistance, bending tensile strength, wear-resistance to drag, rolling, impact and shock, resistance to

pressing-in representing significant constructional parameters.

For special applications, such as, for example the construction of riding and sports grounds, plastics grid plates have proved good. Such grid plates are known from DE 197 20 006 C2. As a result of an ingenious structure of elevations and openings, on the one hand grid plates enable there to be surface-consolidation on which it is possible to walk or drive and on the other hand avoid sealing as a result of their water-controllability.

The areally laid grid plates are laid directly on the substratum, such as gravel, grass, loam or humus. A layer of sand or ballast can, however, also be applied to the substratum in order then to lay grid plates on this layer. It is possible to compensate for instances of unevenness in the ground by means of the layer of sand or ballast. Depending on the use of the sports ground, if applicable a tread layer is applied to a thickness of several centimetres. The tread layer, which together with the grid plates forms the superstructure of the sports ground cover, in the case of riding grounds as a rule consists of a bedding of sand, of a bedding of sand provided with aggregates (wood or plastics chips) or exclusively of wood chips. Depending on the stress and strain and composition of the tread layer, the latter has a thickness of between 8 to 15 centimetres, measured from the upper plate of the grid plates.

The comparatively high costs of grid plates when laid out on large areas and also their uneven structure are disadvantageous, however.

Coverings with a surface structure that is uniform and visually attractive are known from DE 197 33 588 A1. The water-permeable covering is produced from mineral aggregates and organic bonding agents. The mixture is built up in the not yet hardened and deformable state. Mostly organic binding materials come into consideration as binding material that is mixed together with mineral aggregates to form a charge and is processed further before hardening.

What is disadvantageous about these coverings consisting of bound mineral aggregates is the lack of bonding with the substratum, this impairing the mechanical stress and strain precisely in the case of freeze-thaw cycling in grounds that are outside. Chemical, physical and biological corrosion of building materials, weathering, destruction of the subsoil lying underneath can result from this.

It is precisely public building promoters therefore who want to have ground coverings that do not seal the surfaces and allow large areas which bear high mechanical loads, for example as a result of vehicles, in a problem-free manner, to be covered inexpensively.

Against this background an object of the invention is to specify a water-permeable ground covering of the type in the preamble which even in the case of complex shapings is inexpensive in comparison with known ground coverings and grid systems. As regards the mechanical loading capacity, the ground covering should not result in any limitations in the use of the covered areas. In addition, a method for producing a ground covering is to be specified that allows the covering to be laid in a simple and inexpensive manner.

In accordance with the invention, the object that is set with regard to the ground covering is achieved by means of the features of claim 1. Accordingly, the ground covering has a multi-layered structure with a superstructure and a substructure, with the substructure having at least one layer of sand on the substratum side and a layer of ballast on the superstructure side. The average size $k_{ballast}$ of the undersize particles in the ballast amounts to 5 mm or more.

In practice, it has been identified that the service life and loading capacity of a covering consisting merely of grid systems or bound, mineral aggregates is limited. As a result of the structure of the covering in accordance with the invention consisting of a superstructure and a substructure it is possible to adapt the positive properties with regard to the water-permeability of a superstructure, consisting of bound, mineral aggregates, universally to the substratum. The bulk material of the substructure enables there to be uniform load-distribution in the substratum that lies underneath so that even punctiform pressure loads that act on the superstructure are introduced into the substratum so that they are distributed over a large area over the layer of sand on the substratum side and thus the static and dynamic pressure-loading capacity of the superstructure is decisively improved in comparison with known solutions.

A further improvement is brought about by the substructure in its water-permeable passage to the superstructure as regards water-controllability. It is precisely in the case of a critical substratum that has a high proportion of loam that the substructure is able to supplement the water-storing capacity of the superstructure. Thus the surface water is taken up by

the substructure through the superstructure and is distributed horizontally. Thus enormous quantities of water can be taken up within a short time and stored temporarily until the substratum or further drainage facilities drain off the water. This drainage capacity can be attributed to the high voidage so that problem-free installation is possible even in water-protection regions. This voidage as well as different rock sizes and sorts of materials result in excellent sound-absorption.

Tests have shown that the ground covering in accordance with the invention is able to demonstrate excellent water-absorption values. In a field analysis, the water-absorption values of the ground covering were determined and compared with the values of a conventional water-permeable sports-ground construction in accordance with DIN 18 035-6, section 5.1.6.3 and 5.1.6.2. In this connection, the requirements of DIN 18 035-6 were met many times over. Thus a sample with a layer thickness d_o of the superstructure of 47 mm resulted in a water-absorption value k* = 0.51 cm/s. The requirement according to DIN 18 035-6, Table 3, amounts to >0.01 cm/s.

The grain size of the ballast in the substructure has a further favourable effect upon the water-absorption value and water-controllability of the ground. This promises excellent values given an average grain size for the undersize particles of 5 mm or more. Tried and tested average grain sizes $k_{ballast}$ of the ballast lie in a range between 5 to 16 mm, 16 to 22 mm or 16 to 32 mm. That means that the layer of ballast is composed of ballast with different grain sizes, with the grain of a layer of ballast lying in one of the ranges mentioned. The average layer thickness d_s of the compacted layer

of ballast preferably amounts to between 400 and 500 mm.

The grain size of the aggregates also has a substantial influence on the infiltration capacity of the ground covering. Aggregates whose average grain size lies between 1 and 7 mm are particularly preferred. As previously mentioned, the layer structure of the ground covering in accordance with the invention has a favourable influence on the mechanical resistance values so that even values of over 5 mm are possible for the average size of the grain without a substantially increased risk of rupture occurring. The infiltration capacity can be further increased with this grain diameter. In addition, with these values the drop in infiltration capacity as a result of the entry of mineral and organic fine parts over time remains low.

The open-pore structure of the superstructure results in high coefficients of friction on the surface so that the ground covering is suitable as a non-slip cover for carriageways, footpaths, steps and presentation spaces and thus reduces the risk of accidents.

Favourable layer thicknesses for the superstructure with regard to pressure-loading capacity and good water-permeability lie between 30 and 60 mm. Of course, lower values are also possible, in which case then concessions have to be made with regard to pressure-loading capacity. Greater layer thicknesses for the superstructure only bring about slight improvements for the pressure-loading capacity and increases the costs of a ground covering. The optimum for most cases of application therefore lies in the range mentioned above.

Generally, the grain-size distribution is defined according to DIN 66145. The parameter n amounts to at least 9 and is determined whilst disregarding 1% oversize and undersize particles in each case.

The binding material is preferably a two-component polyurethane binding material. A two-component epoxy resin binding material or a one-component polyurethane binding material can be used in exactly the same way. Two-component epoxy resin binding materials are made available, for example, by the firm of Koch Marmorit under the trade name Kryorit.

An important advantage of the use of two-component epoxy resin binding material can be seen in its environmental compatibility. The ground covering in accordance with the invention does not, for example, have any toxic effect at all upon mould fungi and is considered difficult to break down microbially. Nevertheless, substances that can be eluted from the ground covering can easily be broken down, as material tests have shown. As washing tests prove, there is no chemical interaction between surface water and the covering materials so that surface water that seeps through the covering can be introduced into the sewerage system in an untreated state or can safely drain off into the groundwater. Finally, the ground covering in accordance with the invention can be disposed of after its phase of use in an earth- or ballast-washing system without any negative environmental effects. Alternatively, after comminution, reuse thereof as granular material is also possible.

When processing the binding material, two methods are distinguished. If the components of the superstructure or substructure that are present as chippings or sand

are to be stabilized, these are advantageously mixed with the previously homogenized binding agent in situ and laid out. When ballast or other comparatively coarse granular material is stabilized, epoxy resin or polyurethane and hardeners are also mixed in situ and sprayed in liquid form onto the ballast surface. The binding agent flows into the depths and thereby bonds the individual ballast grains or the granular material one with the other.

The binding materials mentioned as a result of the high binding force enable any bulk materials to be combined as a result of very good adhesion in the range of adhesive and capillary action. This additionally contributes to the static and dynamic pressure-loading capacity of the ground covering that has been mentioned. Bonding of adjacent layers of the superstructure and substructure is particularly effective for high loading capacity so that it is also possible for vehicles to drive on the ground covering.

Very often for a visually attractive configuration of spaces colouring of the ground is desired. By using coloured quartz sand or natural stones as an aggregate it is possible to choose from over 200 colour variations so that practically no limits are set on the coloured configuration of a ground covering. Architects in particular know how to use these coloured effects in an impressive way.

In addition to the static and dynamic resistance values that are important for suitability as a carriageway-covering, the ground covering in accordance with the invention as a result of the high voidage also absorbs the sound of vehicles in a clearly better way than, for example, asphalt. Particularly favourable values

result in the case of a voidage of at least 45% in the superstructure.

Further advantageous embodiments of the invention with respect to the ground covering follow from the features of claims 11 to 14.

In accordance with the invention the object that is set with regard to the method for producing the ground covering is achieved by means of the features of claim 15. Accordingly, the production is effected in accordance with the following method steps:

- application of a still deformable mixture of binding material and sand to the substratum,
- compacting of the binding-material/sand mixture,
- application of a still deformable mixture of binding material and ballast to the layer of sand,
- application of the upper layer consisting of a still deformable mixture of aggregates and binding material to the layer applied last,
- compacting of the still deformable mixture, and
- hardening.

Intensive bonding of the layers one with the other results if directly after compacting the first layer the next layer is applied before the layer that lies underneath hardens. This calls for uninterrupted application and compacting layer by layer.

Further advantageous embodiments of the invention with respect to the ground covering follow from the features of claims 16 to 20.

Advantageous embodiments of the invention are explained in the following with reference to the attached drawing, in which:

Figure 1 shows a diagrammatic cross section through a ground covering that has been applied to a substratum with a double-layer substructure, and

Figure 2 shows a diagrammatic cross section through a ground covering that has been applied to a substratum with a three-layer substructure.

Figure 1 graphically shows in a cross section the multi-layered structure of the ground covering 1 in accordance with the invention. In the present exemplary embodiment the latter has three layers, the lowest course of which, the substructure 2, is applied to a substratum 3. Before the substructure 2 can be applied, the substratum 3 must first be prepared. This is dug to a frost-resistant depth of 40 to 60 cm. This digging depth is recommended so that the connection between the substructure 2 and the substratum 3 remains unaffected by the erosive effects of freeze-thaw cycling.

The substructure 2 itself is composed of a course of sand on the substratum side, the so-called layer of sand 4, and the layer of ballast 5 lying on top. For this is first added a charge of binding material and sand that are mixed together. The binding material is a two-component polyurethane binding material. A two-component epoxy resin or a one-component polyurethane binding material can be used in exactly the same way. After the charge has been added, the mixture is then to be processed without interruption as long as it is still deformable and has not hardened. This takes

place by applying the layer of sand 4 to the substratum 3 in an as uniform and planar manner as possible. The layer thickness d_{sand} of the compacted layer of sand 4 amounts to at least 20 mm.

After the compacting and the hardening, which is already starting, of the layer of sand 4, the layer of ballast 5 is applied. The average grain size $k_{ballast}$ of the ballast in the case of the present embodiment lies in a range between 5 to 16 mm, with the average size of the undersize particles amounting to 5 mm. Uniform properties are obtained with this narrow grain-size range. Here as well the ballast is mixed with binding material in order to apply the mixture as uniformly as possible to the layer of sand 4. Subsequently, the layer of ballast 5 is compacted with a mechanical vibrator. The layer of ballast 5 then has an average layer thickness d_s of approximately 500 mm.

Finally, there follows the build-up of the open-pore superstructure 6 that is visible in the finished state. In the first instance, binding material in a quantity of 150g/cm² is sprayed into the layer of ballast 5 that supports the superstructure 6 in order to achieve a firmer connection between the superstructure and the substructure 6 and 2 respectively. The depth of penetration of the binding material amounts to approximately 150 mm. Even before the binding material hardens, a layer of mineral aggregates is applied.

Here as well this is a mixture of mineral aggregates that is mixed with binding material and is applied in the still deformable state. The aggregates that come into consideration are selected from quartzite, granite, basalt and quartz, with coloured granite being used in the exemplary embodiment that is being described. The average size of the granite grain lies

in the range between 2 and 5 mm. The grain-size distribution is defined according to DIN 66145 with a parameter of at least 9 and whilst disregarding 1% oversize and undersize particles in each case.

After the mixture has been applied, this is compacted with a roller and smoothed with a bladed smoothing screed. Compacting is preferably effected with a contact pressure of 10 to 50 N/cm². The superstructure after compacting has a layer thickness d_o of 50 mm. After compacting, the superstructure is hardened. The ground covering can then be loaded.

Basically, before applying a layer to a layer that lies underneath it is not necessary for the layer that lies underneath to harden. On the contrary, application to a layer that has not yet hardened results in better connection of the layers one with the other.

An alternative embodiment of the ground covering 1 in accordance with the invention that can be loaded to a greater extent as a result of an additional layer of sand 4' is shown in Figure 2. The additional layer of sand 4' is applied to the layer of ballast 5 and like the layer of sand 4 on the substratum side is also stabilized with binding material. For better adhesion, binding material is sprayed into the layer of ballast 5 before the layer of sand 4' is applied. After compacting, the build-up of the superstructure 6 is effected in the same way as described for the embodiment in accordance with Figure 1.

List of reference numerals

1	Ground covering
2	Substructure
3	Substratum
4, 4'	Layer of sand
5	Layer of ballast
6	Superstructure